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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : B30B 9/14 A1

(11) International Publication Number: WO 92/1371

(43) International Publication Date: 20 August 1992 (20.08.92)

(21) International Application Number: PCT/US92/00939

(22) International Filing Date: 6 February 1992 (06.02.92)

(30) Priority data: 654,731 12 February 1991 (12.02.91) US

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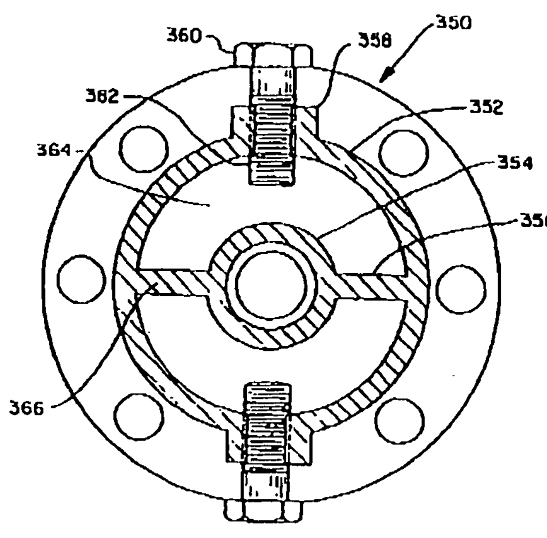
(81) Designated States: AT (European patent), AU, BE (European patent), BR, CH (European patent), DE (European patent), DK (European patent), ES (European patent), FI, FR (European patent), GB (European patent), GR (European patent), IT (European patent), JP, LU (European patent), MC (European patent), NL (European patent), NO, SE (European patent).

Published

With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: ADJUSTABLE COMPRESSION SCREW DEVICE AND COMPONENTS



(57) Abstract

A modular screw device (10) having at least one processor housing component (100, 140, 160, 200, 250) or discharge housing component (350, 350', 380) that can be altered to adjust the compression or drainage characteristics of the device. Compression housings (100, 140, 160) are adjustable by changing liners (104, 142, 150, 164), drain housings (200, 250) are adjustable by adjusting the spacing between a plurality of axially stacked rings (202, 260) and discharge housings (350, 350', 380) are adjustable by pegs or bolts (353, 362, 388, 390, 392) movable radially into the flow bore upstream of the discharge opening. Whether or not adjustable, the dicharge housing (300) preferably includes a central bearing member (310) for supporting the screw and plug breaker plates (306) extending between the housing wall (322) and the bearing member.

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ADJUSTABLE COMPRESSION SCREW DEVICE AND COMPONENTS

Background of the Invention

The present invention relates to compression screw devices, especially of the type used for processing fiber, chip, and similar cellulosic stock material.

Among the various compression screw devices used in processing cellulosic and similar material, a variety of primary and sometimes secondary functions are accomplished. Such functions include dewatering, consolidation for feeding into a downstream piece of equipment, and/or refining under high pressure steam or infusion of chemicals. The properties of the stock material, such as water content, density, effective friction, resilience, and the like, must be taken into account in designing the important variables for the compression screw device, such as required thrust, compression ratio, drainage hole size, and the like.

Currently, such screw devices are in essence, custom designed and fabricated for each application from one of several distinct base models. Typically, the devices are sized for the most severe application that can be encountered for a given base model and thus carry an unnecessary cost premium when purchased for use in a less severe application. Moreover, each base model is conventionally optimized with the limited objective of accomplishing the particular end use application.

Once a particular compression screw device has been designed and fabricated, adjustment prior to delivery to the customer may be possible, but is usually limited in scope and very labor intensive. After delivery to the customer, significant adjustments are virtually impossible without disassembly of the device, including the screw. The ability to adjust the compression in the field, without

changing or removing the screw, would represent a significant advance in the state of the art. Moreover, the ability to adjust the compression on-line, without disassembly or removal of any portion of the screw device, would represent a major advance.

Summary of the Invention

It is, accordingly, an object of the invention to reduce the cost, complexity, and fabrication time, required for the design and manufacture of a compression screw device once the end use application is known.

It is a more particular object to provide functional modules that can be assembled and adjusted for use in fabricating a variety of compression screw devices for both dewatering and sealing applications, including screw presses, plug screw feeders, and refiners.

It is yet another object of the invention to provide housing modules, such as compression housings, drain housings and discharge housings, in which the compression can be adjusted without disassembling the entire device and removing the screw.

These objects are accomplished in accordance with one aspect of the invention, by providing a compression housing having a segmented outer portion adapted to support replaceable liners of varying thickness. The effective flow cross section through such compression housing, is thereby defined by and dependent on the variation, of only the liners, or by a combination of the liners and the unlined segments. Moreover, such compression housing can include drain holes, provided either in the liners, or in the outer segments. In the preferred embodiment of this aspect of the invention, anti-rotation bars can be supported to project into the screw bore an adjustable distance, without removal of the screw. In one variation, both the anti-rotation bars and the effective flow cross

section, i.e., compression, can be adjusted independently of each other.

The objects can also be achieved in accordance with another embodiment of the invention, in screw device configurations that may or may not have an adjustable compression housing of the type summarized immediately above. For example, in a screw device configuration having a drainage housing in which the material undergoes high compression while draining, the combination of a novel drainage housing and an adjustable discharge housing immediately downstream of the drainage housing permits adjustment of the compression in the drainage housing. Moreover, in accordance with the preferred embodiment of this aspect of the invention, the compression can be adjusted on-line, without disassembly or removal of any portion of the screw device.

The novel drainage housing has a plurality of coaxially stacked rings with spacers therebetween and bolts or the like traversing the rings to draw them tightly together. The stacked rings thus have sufficient space to define radial channels by which pressate is drained from the screw bore defined by the internal inner diameter of the rings. Preferably, the inner profile of each ring has slots formed therein for supporting one or more axially extending anti-rotation bars. Notches are provided on the outer diameters of the rings for engaging frame supports to prevent rotation of the stacked assembly. The spacer thickness can easily be adjusted in the shop to retain the desired drain characteristics.

In another aspect of the present invention, the novel drainage housing, and each of a variety of novel discharge housings, can be used independently of each other, with or without the novel compression housing aspect of the present invention. The discharge housing in accordance with the present invention, includes a substantially tubular casing

and a cup-like bearing member supported coaxially within the casing, by plates connected between the casing and the bearing member. These plates not only support the bearing member, but also break up the condensed material as it advances from the downstream end of the screw toward the discharge opening of the device. The provision of the bearing member permits the use of a screw having a stem at its downstream extremity, for rotational support within the bearing member, thereby improving performance relative to unsupported screws.

Whether or not the screw is supported in a bearing, the discharge housing in accordance with the invention has breaker plates extending radially inwardly from the casing inner diameter at least half the radial distance to the axis. Although the compression of the device can be adjusted by substituting a different discharge housing having a greater or lesser number of such breaker plates, or plates of thicker dimension, the preferred adjustment of compression is accomplished by providing a plurality of pegs or bolts that penetrate through the casing to project a variable distance into the discharge housing bore. These pegs not only adjust compression, but provide an additional shearing effect on the material, which can be beneficial, particularly for chemical impregnation applications.

Thus, the compression characteristics of virtually any type of compression screw device can be adjusted on line, by the use of a discharge end housing having the radially adjustable pegs. The pegs can be manually or automatically adjusted by a process control system on line. The advantages of using the adjustable pegs for compression adjustment include reduction of inventory of screw parts and screw housings, since a given screw and housing combination can be adjusted to meet a variety of compression requirements. Moreover, the compression can be varied without disassembling the screw press. This

eliminates expensive downtime. The resistance pegs contribute to the shearing and abrading action on chips, which opens up the chips for optimal chemical impregnation. The opening of the chips in the discharge housing occurs immediately before the chip plug discharges from the device and expands into the liquor bath, optimizing chemical pickup.

The inventors believe that no one in this field of technology, previously considered using interchangeable modules, at least one of which is adjustable, for fabricating at least three distinct types of compression screw devices, e.g., screw presses, plug screw feeders, and press refiners, which are capable of performing simple dewatering to more complicated sealing and refining functions, for a range materials including fibers and chips.

The present invention minimizes the total number of different parts and reduces engineering time for design and upkeep of drawings. This also reduces manufacturing cost and inventory costs. The number of spare parts required to be kept by the supplier and the end user is significantly reduced. Furthermore, the modular feature of the invention allows tailoring the machine to the specific application for improved performance. Such tailoring avoids the use of larger or heavier components than are required for the needs of the end user, therefore making the machines more cost effective. The modularity also allows easy modification of machines operating in the field if the operating conditions change, e.g., if the machine is used for an altered feed stock. At least one of the modular components is inherently adjustable during fabrication or in the field, to optimize one or both of the compression ratio and drain hole pattern.

Brief Description of the Drawings:

These and other objects and advantages of the invention will be described below in the context of the preferred embodiment with reference to the accompanying drawings, in which:

Fig. 1 is a longitudinal view of a modular compression screw device including the invention, partially cut away to reveal the screw;

Fig. 2 is an external perspective view looking from the discharge toward the inlet end of a modular screw device of the type shown in Figure 1;

Fig. 3 is a cross section view of a compression module housing but without drain holes, as would be seen if taken through lines 3-3 of Fig. 2;

Fig. 4 is a perspective view of another compression module housing which has drain holes;

Fig. 5 is an elevation view of a third compression housing module, which has drain holes;

Fig. 6 is a cross section view taken along line 6-6 of Fig. 5;

Fig. 7 is an exploded perspective view of the drainage module housing of the device shown in Figure 2;

Figs. 8 and 9 are front and side views, respectively, of one of the plurality of rings in the drainage module housing of Figure 7;

Figs. 10 and 11 are front and longitudinal section views, respectively, of one embodiment of the plug breaker discharge module;

Figs. 12 and 13 are sectional end and side views, respectively, of a second plug breaker module, which includes a variable shear penetration into the plug;

Figs. 14 and 15 are end and side views, respectively, of a third embodiment of the plug breaker module, which includes axially staggered, variable length pegs for penetration into the plug;

Fig. 16 is a longitudinal view of a screw device configured in accordance with the invention and adapted for feeding chip plugs into a chemical impregnation bath;

Figure 17 is an end view of an alternative drainage module housing, as viewed axially intermediate the ends; and

Figure 18 is a view similar to Figure 13, showing the preferred form of the resistance peg and associated adjustment mechanism for the discharge housing.

Description of the Preferred Embodiment

Modularity Overview

Figure 1 shows a longitudinal view of a modular compression screw device 10 in accordance with the invention, wherein each of the five main modules is indicated as A, B, C, D, and E. The functions of these modules are well known in the relevant field of technology, but the modular implementation of those functions using adjustable modules whereby the overall characteristics and performance of the device can be matched to a wide variety of end use applications, is considered novel.

Module A is a drive module including a drive housing 12, a drive bearing assembly 14 within the drive housing, and a drive flange 16 at one end of the drive housing. The details of the internal configuration of the drive module are not important to the invention, except that at least two, and preferably at least three, different thrust capacities, i.e., low, medium, and high, are available from three distinct, interchangeable drive modules, each of which has a substantially identical drive flange 16. The drive module A has a drive shaft 18 with a free end 20 adapted to be connected to a drive motor or the like (not shown), and an opposite end which has a shaft flange 22 or the like securable in fixed relation with a mating flange 24 or the like on the screw module D.

The screw module D includes a first portion 26 including screw flange 24, connected for rotation to the drive module, and in particular, to the shaft flange 22. The operative portion of the screw includes a shaft 28, which preferably has a straight portion 30, an outwardly tapered portion 32, and another straight portion 34. Screw flights 36 project from the portions 30,32,34 of the screw, in a manner well known in this field of technology. The screw discharge end 35, which has no flights, is supported by a bearing or similar mechanical structure 58, to maintain a central position along the nominal axis of the screw device 10.

The feed or stock material enters the screw device 10 through an inlet module B which includes an inlet housing 38, a first inlet flange 40 detachably mated with the drive flange 16, an inlet opening 42 for receiving the stock material into the device, and a second inlet flange 44. One or more processing components C1,C2 define a processor module C having a processor housing 46, and a first processor flange 48 mated with the inlet second flange 44, and a processor second flange 50. The discharge module E, includes a discharge housing 52, a discharge flange 54 mated with the processor second flange 50, and means defining an opening 56 for discharging consolidated material from the device. A biased pressure valve (not shown) may optionally be attached to the end module E. The modules B, C and E define a bore for receiving the screw module D and cooperating therewith to process the feed material.

Viewed in relation to the remainder of the device 10, the screw module D functions as a unitary piece with the screw flange 24 at the upstream end, a second portion 30 disposed in the inlet module B in fluid communication with the inlet opening 42 for receiving and advancing the stock material toward the processing module C, a third and fourth

portion 32,34 disposed in the processing module C for consolidating the stock material by compressing the material against the bore of the processor housing 46, and a fifth portion 35 at least partially disposed in the discharge module E.

As used herein, the term "consolidation" should be understood in the most general sense, to mean the bringing together of flowable solids into a more intimate contact with each other, whereby the volume of the material is reduced and the bulk density of the material is increased. In this context, consolidation includes the removal of water or liquid in which the solids are suspended in a slurry; the compaction of dry solids such as fibers and chips, into a plug; or the pressurization of solid material to physically break down cellular structure or the like, thereby increasing the solid's density. Thus, consolidation can occur as part of a variety of end use applications including dewatering, with or without feeding, compaction, refining, etc.

The screw device 10 of Figure 1 is adapted to receive wood chips or similar cellulosic material through the inlet module B, convey the chips toward the right, into the processing module C, where the chips are consolidated as they are conveyed farther to the right by the screw flights 36, and compressed in the space 60 between the increasing taper on the screw shaft 28, and the constant diameter bore 62 of the compression housing 46 (component C1) of processing module C. Further consolidation occurs in the module drain housing 47 (component C2) of the processing module C. In the illustrated embodiment, the bores of housings 38,46,47 and 52 of the inlet, processing and discharge modules, define a substantially constant screw wall or bore diameter, although breaker bars or the like 49 may optionally project into the bore. The way in which the stock material is consolidated, strongly depends on the

shape and power of the screw module D, the wall characteristics of the processing and end modules C,E, and the nature of the restriction at discharge modules E for partially blocking flow in the seal annulus 64 between the screw end portion 34 and the bore 62.

It is desirable that one or more of the modules be adjustable so that the device can be optimized for the particular end use application. Adjustability in one sense means the capability to initially fabricate a module component according to standard specifications, and adjust the internals of the component during fabrication of the compression screw device. The second aspect of adjustability is the capability to make such alterations in the field, either during field testing or during normal use when compensation for the effects of wear or a change in feed material should be made. The preferred implementation of the present invention is directed to a screw device having adjustable processing modules C and end module E. The adjustability is primarily with respect to the effective flow cross section of the longitudinal flow bore including the processing bore 62, seal area 64 and discharge opening 56, and can be achieved without removing the screw module D from its normally supported orientation on the device axis, i.e., coaxial with the processing bore 62. The adjustable compression housing component C1, drainage housing component C2, and the discharge module E will each be described in detail immediately below, with Fig. 2 as a frame of reference.

Preferred Compression Housing Component

The embodiments of compression component C1 will be identified with the number series 100 as shown in Figures 2-6, and may be used either in a modular device as described herein and shown in Figure 2, or as an integral part of other plug screw feeders and the like to overcome

the following problems. For proper performance, the material must be compressed enough to form a steam seal or pressure type plug, but the plug must be loose enough to allow continuous conveying to occur. In most instances the screw device operates in a narrow band. If the compression of the material is too high the plug screw will draw excessively high motor loads and possibly stall. If the compression of the material is too low a gas type seal cannot be maintained. Often, slight variations in the bulk material properties will move the operation of the plug screw feeder outside its narrow band, resulting in blowback or stalled conditions. Since these devices are used in continuous process systems, any interruption in their continuous operation can disrupt the functioning of an entire plant.

When a problem develops with a plug screw feeder, the unit is usually immediately disassembled and parts are modified either by machining or by building up various regions of the housings or screw in an attempt to alter the compression ratio. Since this is a trial and error procedure it can become a very time consuming and costly undertaking to fine tune a unit for a particular feedstock, particularly when this must be done in the field.

The purpose of the new compression housing, is to provide a means to alter the compression ratio of an installed plug screw feeder without having to completely disassemble the unit or machine any of the components. As shown in Figure 3, the invention includes a set of casings 102 which surround the compression screw portion 32, and removable liners 104 which can be changed to either reduce or increase the total compression ratio of the unit. The casings 102 can either be segments of a cylinder, to be used in conjunction with uniform screw flights which would have an increasing shaft diameter; or the casings can be segments of a cone, to be used in conjunction with tapered

screw flights. The casings 102 form the component housing to contain the internal pressure developed by the compression of the conveyed material. The liners 104 are provided in thicknesses varying by approximately 1/8 inch increments. The varying thickness of the liners 104 allow the effective cross-sectional area of the screw bore to be changed, which results in a change in the overall compression ratio of unit. The liners 104 also function to resist wear.

Having a plug screw feeder installed in the field with removable housing liners greatly simplifies fine tuning the compression ratio in the field. For example, assume a plug screw feeder unit was installed to convey wood chips into a high pressure refining system. At the installation assume the chip moisture content was lower than expected, resulting in high plug screw feeder motor loads and intermittent stall conditions. Correcting this situation would require reducing the the compression ratio of the unit. With removable liners this is accomplished in the following manner. The split casings 102 are taken apart along flanges 106, the installed liners 104 are removed and a spare set of thinner liners are put in place. For example, reducing the bore of the liners by 1/4 inch on the radius would result in reducing the compression ratio by approximately 19%. This would take the plug screw feeder out of the high load, stalled condition and allow it to run continuously at reasonable motor load levels. No machining of parts would be required and the screw would not have to be removed from the unit. Therefore none of the drive components or the connected pressure vessel parts would have to be disturbed. The casings may be directly or indirectly connected to end flanges 108, which, if present, may or may not require removal and reattachment to the remainder of the screw device. The replacement in accordance with the invention can be accomplished within

about an hour as compared to a minimum of 24-36 hours required to change the compression ratio conventionally by machining either the screw or the bore of the housings.

For any compression type screw device to convey material, the material must be prevented from rotating with the screw 32. Thus the frictional resistance radially in the surrounding compression wall must be greater than the frictional resistance of the screw flights and shaft. Conventional plug screw feeders normally have a series of grooves either cast or machined into the housings for this purpose. The present invention does not utilize a series of grooves or bars in the housing, but rather anti-rotation bars 110 are sandwiched between the adjacent casings 102. The anti-rotation bars 110 protrude radially beyond the inner surface 112 of the liners 104 by a minimum of 1/4 inch. The radially inward projection height of the bar 110 increases as the thickness of the liners decreases. The distance from the inner edge 114 of the bar 110 to the outer diameter edge 116 of the screw flight would be held constant.

Thus, in the broadest aspect of this feature, a screw press housing 100, whether in the modular configuration or in a more conventional configuration, defines a substantially cylindrical or axially tapered first bore 118 for coaxially receiving a screw 32. The housing 100 is formed by connecting together a plurality of axially elongated casing members 102, each casing member in cross section having an inner, concave surface 120 which defines an arc segment having a first circumferential span and a first radius of curvature, and an outer surface 122 defining the exterior of the housing 100. Fixture means, such as shoulders or flanges 106, extend radially from the ends of each segment, for attaching together adjacent casing members, whereby the inner surfaces 120 of the connected casing members form a first substantially

cylindrical or conical bore 118. A plurality of bar members 110, are situated respectively between the flanges 106 of two attached casing members 102. The bars have an inner edge 114 that extends radially inward into the first bore 118, toward the housing axis 124. An axially elongated liner member 104 is coaxially retained within the first bore 118 and, when viewed in cross section, has substantially the same circumferential span as its associated casing member 102. The liner may optionally be split and overlapped as at 126 to assure a good fit. The outer wall 128 of a given liner is supported radially by the associated casing member. The inner wall 112 of each liner member has a second radius of curvature smaller than the first radius but is large enough to ensure an annular gap 132 relative to the screw flights 36 that operate in substantially the same plane as the given cross section. The circumferential ends 134,136 of each liner are juxtaposed with the respective bar member 110. Preferably, the inner edge of each bar member 114 extends radially closer toward the housing axis 124 than do the liner inner walls 112, e.g., the distance between the edges 114 of diagonally opposed bars is only slightly larger than the screw flight diameter.

As shown in Figure 3, adjustment bolts 138 threadedly pass through the casing members 102 and can either engage mating threads in the liner 104 or merely provide stops surfaces, so as to adjust the radial limit position of the liner relative to the casing member. The replaceable liners 104 can extend the entire length of the housings or optionally can be positioned only in the high compression zone, near the end of the screw.

As shown in the embodiments of Figures 4 and 5, the screw bore of the housing can be defined partly by the liner inner walls and partly by the inner surfaces of the casing members. Moreover, the casing members need not have

the same material thickness or radii of curvature. When taking into account the ability to utilize liners of various thickness, the inner surface of the casing member may have a radius of curvature that is the same as, greater than, or less than the radius of curvature of the inner wall of the liner member.

In the embodiment 140 of Figure 4, the liners situated in two of four casing members may optionally be in the form of screen plates 142 which have drain holes 144 formed therein. The bar members 146 may be formed with radially extending drainage slots 148 by which extracted liquid can flow to the housing exterior and into an affluent drain basin or the like when the screw rotates in the direction of the arrow. In this embodiment, a spacer or auxiliary liner 150 may be provided between screen plate 142 and the inner surface of casing 152 to facilitate drainage.

As shown in Figure 4, the casing members 152' which surround the screen plates 142 may optionally be formed so as to define a series of axially spaced apart ribs 156 with relatively large openings 154 therebetween. In this variation, the supporting ribs 156 support the inner screen plate 142 directly, or as shown, indirectly through the intervening auxiliary liner 150 which also has drain holes therein. The ribs 156 do not have drain holes, however, the large spacings 154 between each rib provide ample room for drainage to take place.

The embodiment 160 shown in Figures 5 and 6 is another alternative. Two offset sections 162, which cradle the adjustable liners 164, alternate with the other two casing sections 166 that have the same inside radius as the radius to inner edge 168 of the anti-rotation bars 170. The recessed sections 162 with liners 164 do not have drainage holes whereas the non-recessed sections 160 do have drainage holes 172. Providing drainage holes 172 close to

the screw outer diameter prevents a build-up of material over the holes, which would impede liquid flow. The screw flights keep the holes 172 wiped clean, while the liners 164 in the recessed sections still enable the compression ratio of the unit to be changed.

It may thus be appreciated that, depending on the application, some compression screws do not require drain holes, whereas others do. For example, a plug screw feeder of the type shown in Figure 3 does not have drain holes and is used for feeding dry material into a pressurized zone. In other instances, where wet chips are being conveyed, it is necessary to provide drain holes in order for the unit to function properly. Moreover, it is clear that when a compression screw is being used specifically as a drainage press, drainage holes or openings must be present. It is within the skill of an ordinary practitioner in this art to combine the various features shown in Figures 3-6 for the particular end use application. These options include (a) solid casing sections and solid liners, (b) solid casing sections and one or more screen liners and/or auxiliary spacer liners supported by the casing sections, (c) a combination of solid and perforated casing sections with solid or screen liners, or (d) solid and ribbed casing sections with perforated liners. All of these options are adapted to use anti-rotation bar members with drainage slots.

The following advantages are obtained with this aspect of the invention. The anti-rotation bars at the casing junctures eliminate the need to have grooves or bars in the housing surfaces, and therefore the wear liners can be one piece, rolled plates. Once assembled, the anti-rotation bars secure the wear liners in the housing and prevent them from sliding or rotating with the material in the tangential direction. This arrangement provides the maximum width of an anti-rotation groove. The shear area

or the wood imbedded in the groove is at a maximum, and therefore the required frictional resistance of the screw flights and screw shaft surface must be much higher before plug rotation occurs, as compared to the conventional use of smaller width grooves.

The screw bore can be increased by decreasing the thickness of the wear liners, however the clearance between the anti-rotation bars and the outside diameter screw flights can be maintained. In conventional units if the bore of the housing is increased, then the clearance between the O.D. of the screw flight and the I.D. of the housing or anti-rotation bar imbedded in the housing would increase, resulting in less effective resistance to plug rotation.

Preferred Drainage Housing Component

The second component which is preferably adjustable in the processing module C is the drainage component C2 as indicated at 200 in Figure 2. Conventionally, screw presses which are used to drain fibrous materials generally use split housings with drainage holes or axial slots to drain water away from the material as it is compressed within the housings. High compression units generate enough internal pressure that it is often necessary to support the perforated housing or the slotted housing sections with support ribs. A popular construction of high pressure units consists of bars placed axially along the length of the screw, assembled with a slight clearance between each bar. This configuration results in drainage slots along the length of the screw. The bars are held in place and supported by a heavily ribbed set of cages which when bolted together completely surround the compression screw. The housing must be a split design for assembly reasons, but this weakens the housings since the split results in the ribs being loaded as curved beams with

restrained ends at the bolted joints. The ribs must have a heavy thickness and deep cross-section, so the cost of the drain bars and supporting ribbed housings is high. Such housings require extensive machining and each individual bar must be ground to fit properly in the assembly.

The details of new drainage housing 200 in accordance with the invention are shown in Figures 7-9. The housing is made from a plurality of rings 202 generally 3/8 inch to 1/2 inch thick which are assembled in a stack. The gap 204 between the individual rings is set by shims 206 placed over the assembly bolts 208 which extend through the entire stack of rings and clamp the assembly together by drawing the rings toward each other. The gap between the individual rings generally ranges from .010 inch to .040 inch.

The inside diameter 210 of the rings is slightly larger than the outside diameter of screw flights passing therethrough. Two diametrically opposed grooves 214 are machined in each ring, resulting in slots 215 extending the length of the stacked assembly. Positioned in each slot is an anti-rotation bar 216, the longitudinal ends 218 of which are secured with bolts 220 which pass through radial holes in the end support plates 222 (only one shown). The purpose of the thick end support plates 222 is solely to provide bolting for the anti-rotation bars 216. The anti-rotation bars 216 when positioned in the slots 215 protrude radially inward from the inside diameter of the rings, by approximately 1/4 inch to 3/8 inch, along the axial length of the inner surface 210.

The rings 202 preferably do not have a constant thickness along their full radial distance. Approximately 1/4 inch away from the inside diameter 210 of the rings, the front surface 224 of each individual ring is recessed back approximately 1/16 inch. The recessed area 226 of each ring is intended to prevent fines which may pass

through the grooves 214, from building up in the rings and impeding drainage.

On the ring perimeter, a set of opposed notches 228 are positioned 90 degrees out of alignment with the inside grooves 214. In the final assembly of the unit, the outside notches 228 fit over side bars 230 which act as a brace for the ring assembly and provide torque resistance to the unit. The side bars 230 are part of a frame that is rigidly connected to the supporting base 232 of the machine.

Thus, this aspect of the invention is directed to a compression screw device having a drain housing 200 including a screw bore 234 for coaxially receiving a rotating screw and a frame or base 232 for supporting the housing. The housing comprises a plurality of substantially annular rings 202 rigidly stacked together along the housing axis 236, each ring having an inner profile 210 defining a substantially circular opening in alignment with the openings with the other stacked rings to form the screw bore 234. The outer profile 238 of the annulus includes means 228 for engaging the frame, preferably in the form of two diametrically opposed notches which are horizontally oriented relative to the assembled screw device. The frame of the screw device has an elongated, rigidly supported horizontal brace bar 230 having a profile which dovetails with the notches on the stacked rings, thereby resisting torque loads imposed by the rotating screw within the screw bore. Spacer means 206 are interposed between each ring 202, for defining a drainage channel or gap 204 which extends substantially 360° radially from the screw bore to the outer profile where the expressed liquid is collected and drained away. The stacked rings are preferably drawn toward each other so as to be compressed against the respective shims, by a plurality of bolts 208, for example four, which pass

through a respective plurality of uniformly spaced holes 242 in the solid annulus of each ring.

An alternative embodiment of the drainage component, having individual features which may optionally be incorporated into the embodiment described immediately above, is shown as 250 in Figure 17. In this embodiment, shown in an end view as would appear during assembly of the housing, an outer shell 252 having upper and lower portions defines a collection volume where the drained fluids are accumulated and removed. The drainage rings 260 are confined between axially spaced apart end plates or flanges 254 (only one of which is shown in Figure 17), the outer diameter of which defines an annular gap 256 with the shell 252. Unlike the embodiment described in Figure 7, in this embodiment the rings 260 do not have holes for receiving the tensioning bolts, but rather the tensioning bolts 258 span the opposed flanges 254 which, when drawn toward each other, tightly pack the individual rings 260.

Each ring 260 has a substantially circular outer diameter 262 less than the diameter of flange 254 and a substantially circular inner diameter 264, except that the inner diameter has at least one, preferably two diametrically opposed, integrally formed anti-rotation projections 266. These projections 266 are preferably thicker in the axial direction, than the annular body portion 268 of ring 260. A plurality of integrally formed shim portions or regions 270 are also formed on and thicker than the annulus 268, preferably the same thickness as the protrusions 266. In the illustrated embodiment, two integral shims 270 are spaced apart in each quadrant. The rings 260 are aligned so that the protruding anti-rotation projections 266 and the integral shims 270 are in registry in the axial direction, with corresponding structures on all rings in the stack. Preferably, the inner diameter 264

of the ring includes a substantially circular recessed drainage gap 272 as in the previously described embodiment.

The raised or thickened regions defining the integral shims 270 substitute functionally for the individual spacers or shims 206 for establishing the width of the drainage channel such as 204 shown in Figure 7. The raised surfaces on integral shims 270 are ground to a thickness which when in contact with the adjacent ring in the stack, establishes the desired drainage channel radially along the body portions 268. This feature of the embodiment shown in Figure 17 would be used when the required drainage channel is known with substantial certainty for a particular process. An advantage of the integral shim embodiment for setting the size of the drainage channel, is that it eliminates a large number of separate shims and thereby simplifies the assembly of the press.

The integral projections 266 shown in Figure 17, provide the functional equivalent to the anti-rotation bars 216 in the embodiment of Figure 7. When the rings 260 of the embodiment of Figure 17 are assembled together in a stack, the protrusions 266 line up with one another in the axial direction to form what are essentially anti-rotation bars along the full axial length of the ring stack. This reduces cost by eliminating the thick plates at 222 at each axial end of the stack, the separate anti-rotation bars, and the required machining associated with that arrangement.

The size of the drainage rings in the embodiment of Figure 17 can be reduced relative to that of Figure 7, by the feature of arranging the tensioning bolts 258 at the outer diameter 262 of the stack of rings. The rings are supported and positioned by the frame members 232,230 via notch 274 in the outer diameter 262 of each ring, as in the embodiment of Figure 7. Thus, the tensioning rings 258 serve only the single function of drawing the rings toward

each other. In this manner, the outside diameter 262 of the rings can be reduced relative to the embodiment of Figure 7, because the annulus 268 does not carry the holes 242. The thickness of annulus 268 need only be sufficient to support the applied loading which consists of the internal pressure, the torque, and the axial friction forces produced as the processed material is being conveyed through the unit. Eliminating the unnecessary depth of the annulus 268 reduces material costs, makes the pieces easier to manufacture, and keeps the weight of individual rings low enough so that one person can lift them.

One advantage of using the stacked ring assembly for the drainage housing is that a solid ring can withstand much higher internal pressure than a split housing, simply because the ring is loaded in hoop stress tension, whereas a split housing is basically a curved beam with large bending moments at the split joint. In the embodiment of Figure 7, the individual rings 202 are assembled in the field by sliding them over the side support bars 230 and the clamping bolts 208 while the discharge end module is detached. In another advantage, the gap 204 between each individual ring can be adjusted slightly by changing the shims 206 placed over the clamping bolts without removing the rings from around the screw. Thus, the screw remains in the longitudinal bore during axial adjustment of the rings. Compensation for the accumulated length due to large changes in the individual gap requires removal of the discharge module and is accomplished by adding or deleting rings as necessary and assembling the compensation shims at the upstream end of the stack to compensate for any variances in overall length of the assembly.

The stacked ring arrangement eliminates the use of supporting rib cages, which greatly reduces the overall cost of the unit. Assembly time is also reduced as compared to the use of the screen bars and cage

arrangement. The assembly required for the conventional bar/ribbed cage assembly consists of positioning each drain bar in place, shimming between the top drain bars and the clamp bars bolted to the split face of the cage, and then placing the assembled units around the screw and bolting them in place. If the drain bars are not precisely and tightly held in place, a tight plug of material can lift up and dislodge the corner of one bar, and cause all the other drain bars to dislodge as they all become loose. By comparison, the solid rings of the present invention are self contained and cannot come apart except by complete fracture of a ring or failure of the clamp bolts.

Discharge End Module

The modular screw device of Figure 2 preferably includes, as the discharge module E, a plug breaker component 300 of the type shown in Figures 10-15. Any compression screw used for dewatering or forming a gas seal in a continuous feeding operation functions by mechanically squeezing or compressing the material being conveyed. This is done by reducing the cross-sectional area of the screw flight and/or reducing the screw pitch. When cohesive material such as wet wood chips or fiber are handled in a high compression screw, the material often discharges as a hard, dense plug which breaks off into variously sized lumps. The non-uniform lumps adversely affect processing downstream from the compression screw.

When high compression screws are used (to maximize drainage or seal against a very high pressure differential) plug spinning becomes more of a problem because the squeezed out liquid travels to the outside diameter of the screw. This can result in a lower friction coefficient at the screw outside diameter than against the screw shaft. The particles against the screw shaft adhere to the shaft surface as they become dryer, and the outer particles

against the housing bore begin to slide over one another more easily as they become lubricated with the liquid being expressed toward the housing walls. This condition often causes the plug to rotate with the screw, whereupon conveying will cease.

When a compression screw discharges directly into a pressure vessel or impregnation vessel, it is difficult to arrange for the discharge end of the screw shaft to pass through the vessel into a bearing support. Therefore, most conventional compression screws which discharge directly into a vessel are simply not supported; the discharge end of the screw has no bearing support whatsoever. The compressed material essentially becomes the discharge and bearing support. On large diameter, long screws, problems can develop when the screw is forced off-axis as a result of uneven filling at the inlet and thus uneven support of the screw. This can result in galling of the flight outer edges against the housings and in some cases can result in a stalled condition.

The overall object of the preferred end module 300 is to accomplish the three above-mentioned tasks. These are to break up the plug, provide maximum anti-rotation of the plug in the high compression zone, and provide a bearing support for the discharge end of the screw. In the preferred embodiment, the fourth task of adjusting the cross sectional flow area permits adjustment of the compression in an upstream component.

The basic plug breaker end module 300 shown in Figures 10 and 11 comprises a tubular outer housing 302 which bolts directly to the downstream end of the screw housing or processing module such as 200. An internal cup-like bearing 304 is situated on the housing axis 306. The bearing 304 is supported by longitudinal plates 306 that have one end 308 welded to the inside diameter of the outer housing 302 and the other end 310 welded to the outside

diameter of the bearing member 304. The plates 306 are welded tangentially to the bearing member 304 so that in use, the plates are loaded in tension or compression rather than in bending as would arise from a tendency for plug rotation to take place under high compression conditions. The axially extending plates 306 function as knife edges against the passing compressed plug, creating a nonuniform chip velocity. This nonuniform velocity develops shear forces within the plug, which break up the lumps as they discharge from the plates. The shear forces in the particle-to-particle movement within the segments of the plug passing through the plates, also helps fiber the material.

The bearing member 304, is lubricated by water which travels through a bore 312 drilled through one of the breaker plates 306 from the outside wall of the component housing 302 to the closed end 314 of the bearing. The water not only lubricates, but also flushes the bearing, keeping fines out of the area and prolonging the life of the bearing.

The discharge end housing is thus in the form of a substantially tubular housing 302 having a cylindrical wall 316 defining a bore with a longitudinal axis 306 and upstream and downstream, preferably flanged ends 318,320. The upstream or forward portion 322 of the bore is adapted to receive the substantially cylindrical end portion of the screw, i.e., a cylinder having no screw flights. The downstream internal portion 324 of the bore has a plurality of breaker plates 306 rigidly depending from the bore wall 316. The plates are oriented so that the substantially planar opposed sides 326,328 defining the longitudinal and height dimensions, extend substantially parallel with the axial flow direction of the material conveyed by the screw, whereas the cross sectional thickness dimension 330, which confronts the oncoming material, is relatively thin, i.e.,

the frontal area of the plate is less than the area of either side. Preferably, a bearing member 304 in the form of a cylindrical cup is centered coaxially within the housing, so that the open end thereof rotationally supports an axially extending stem portion of the screw. The breaker plates, preferably four in number, are rigidly connected substantially tangentially to the bearing member.

Certain types of wood pulping processes require wood chips to be chemically impregnated. The chemicals which are impregnated into the chips helps to partially break down the chips into fibers and to bleach the wood material. Wood chips are impregnated in the following manner. The chips are compressed in a compression screw device. This squeezes out any undesired liquid imbedded into the chips. As the compressed chips discharge from the screw device, they expand almost back to the original volume. If this expansion takes place with the wood submersed in a chemical liquor, the liquor is drawn into the voids and crevices of the chips much the same way a squeezed sponge upon being allowed to expand will absorb water. In this manner, chemicals which contribute to the pulping process can be impregnated or drawn into the voids and crevices of the chips.

If only the outside surface is exposed to the chemicals, then the innermost portion of the chips will have different characteristics than the outer portions, and poor pulp quality will result. A way to maximize the chemical uptake and optimize the process is to partially separate and open up the chips so that more fiber surface is exposed to the chemicals and the chemicals penetrate uniformly through the chips.

Another consideration is that different wood species and impregnation stages require different amounts of compression and chip fracturing to optimize the process. This historically has been accomplished by changing the

hardware such as screw flights and housings to produce different amounts of compression. This can be a costly process particularly if a large screw press has to be refitted in the field on a trial and error basis until an optimum screw flight, housing combination is obtained.

A plug breaker of the type shown in Figs. 12-16, with added radially adjustable resistance pegs or bolts, helps to optimize the impregnation process in a very cost-effective and efficient manner. Plug breaker discharge housings 350 and 380 provide variable axial resistance to chip flow.

The module 350 in Figs. 12 and 13 has a tubular housing 352, centrally located bearing member 354, and bearing support plates 356 which extend horizontally in opposite directions between the bearing member 354 and the housing 352. As shown in Fig. 13, the support plates 356 extend the full axial length of the housing and are tapered at the upstream end to facilitate the other function of breaking up the material as it flows through the cross sectional area 364 transverse to the housing axis. In this embodiment, two vertically aligned resistance pegs or bolts 360 pass in threaded engagement through bosses 358 in housing 352, whereby the projecting end 362 of each bolt 360 penetrates into the cross sectional area 364 a variable distance that is adjustable externally of the housing. The pegs 360 are located in and supported by the housing 352, upstream of the outlet opening 351.

The discharge end module 350 differs from the module 300 shown in Figs. 10 and 11, not only with respect to the adjustable resistance bolt or peg, but also in the geometric relation to the screw. As shown in Fig. 1, only the stem 58 of the screw enters the discharge module 350, whereas the large, cylindrical trailing end of the shaft immediately upstream of the stem 58, enters the forward portion 322 of the end module 300. The bearing support and

breaker plates 306,356 of end modules 300,350, respectively, impede the axial flow of a plug of chips through the upstream components of the unit, thereby contributing to chip compression. Adding the pegs or bars to the cross section of the discharge housing in accordance with the configuration of end housing 350, further adds to impeding the chip flow. By keeping the cross sectional area 366 of the plates 356 in the embodiment of Fig. 12 to a minimum, as compared with the cumulative cross sectional area 330 of the plates 306 of Fig. 10, increased resistance can be provided by external adjustment of the bolts 360 only as needed, by external adjustment. This allows variability of the compression without the need to disassemble the unit, i.e., without removing either the end housing or the screw.

In a variation of the embodiment shown in Figs. 12 and 13, another embodiment of the discharge module 300 is shown in Figs. 14 and 15. In this embodiment, the housing 382, bearing member 386, and plates 384 are substantially identical with the corresponding structure 352,354,356 of the embodiment shown in Fig. 12, except that six, rather than two, adjustable pegs are provided. In particular, four bolts 388,390 are provided at 90° intervals in the same imaginary plane transverse to the housing axis, whereas two adjustable pegs 392 are provided in 180° opposition through a plane that is offset axially downstream.

The radial adjustability of the pegs not only alters the amount of chip compression in the unit, but the protruding pegs also produce a shearing action on the chip plug as the material passes in and around the pegs. This shearing action effectively opens the chips, exposing the chip interior exactly when expansion begins to take place as they discharge from the plug breaker into, e.g., the chemical liquor of a downstream component. Although manual

adjustment of the pegs is shown, it would be well within the skill of practitioners in this art to mechanize and automate the peg adjustment as part of a process control system for on-line adjustment while the system is running.

Figure 18 illustrates one implementation of a production arrangement for adjusting the resistance peg in the discharge module 350′, which, in other respects, is similar to the embodiment 350 shown in Figures 12 and 13. It should be appreciated, however, that the adjustment mechanism shown in Figure 18 can be used with other embodiments as well.

Although simple bolts of the type previously illustrated can function satisfactorily for a limited period of time, on a full-scale production machine, the resistance pegs would be more robust, as shown in Figure 18. A smooth peg 353 made from an abrasion resistant material is situated in smooth bore 367 in boss 358, immediately downstream of the upstream flange housing 352. A positioner plate 355 overlies boss 358, and has a smooth bore 375 and a threaded bore 373 for receiving anchor bolt 369 and adjustment bolt sleeve 357. Anchor bolt 369 passes through bore 375 into threaded engagement with bore 371 in the boss. The sleeve 357 is secured by nut 359 at the upper surface of plate 355. The lower end of control rod 361 carries a pin 363 for attachment to the peg 353. The control rod 361 slides vertically through sleeve 357 under the direction of a controller. In this fashion, the extent of the projection of the peg 353 into the flow area of the discharge housing 350′ is adjustable.

Modular Screw Design Experimental Results

It should be appreciated that, for example, depending on the nature of the feed material and the downstream processing required, an improved screw device according to the invention, may include one or more of the compression

housings 100, 140, or 154; drainage housing 200; or discharge housings 300, 350, or 380. Fig. 16 illustrates a screw device configuration 700 having only one processing module, the drain housing 200, coupled with the end housing 380, to form a dewatering press used as a plug screw feeder into a chemical impregnation component (not shown). In this configuration, a chip inlet module 400 is connected to the drain module 200, and a drive module 500 is connected to the inlet module 400, for driving a unitary screw 600 that has an increasing taper and full flights within the drain housing 200.

A comparison was made between the modular screw device (MSD) shown in Fig. 16, and a comparably configured screw device including a processing module available from Andritz Sprout-Bauer, Inc., Muncy, Pennsylvania, as the Model 560 Pressafiner component. A comparative chemical impregnation trial with aspen wood was made, with the important result that the MSD incorporating the drain housing 200 and discharge housing 380 of the present invention, produced approximately a 50% higher chemical uptake than the Pressafiner configuration. The MSD also had slightly less fines in the effluent than the Pressafiner configuration. Fiber classifications at comparable freeness were essentially equal.

In the test, the MSD had a 2-1 compression ratio. The Pressafiner configuration was assembled with a standard 4 to 1 combination of worms and collars. The impregnation was in both instances, accomplished in two stages. In the first impregnation stage, all adjustable pegs were set at 5/8" extension into the discharge bore. On the second impregnation stage, all pegs were advanced into a 1-1/4" extension into the plug. This change was easily accomplished from outside the housing without removing the discharge module 380 from the processing module 200, by manually turning the pegs (bolts) to the desired depth. In

a production mode, this penetration is preferably achieved with an automatic compression control system 394 for effecting peg movement from outside the housing. In the Pressafiner configuration, no change was made between stages, as this would have required disassembly of the unit. The chips discharged from the MSD were collected and observed in order to determine the settings for the bolts in the two stages. At the indicated settings, the chips discharging from the unit were very uniform in particle size and condition. Virtually no whole chips were observed. The shearing and abrading effect of the resistance bolts and the bearing support plates very effectively split open the chips in a manner which is conducive to maximizing chemical uptake.

During this test, visual observations were made of the individual drainage rings associated with drainage housing 200. In both the first and second stage of pressing, approximately half of the drainage rings, those toward the discharge assembly 380, were showing drainage. The last third of the rings were showing significant amounts of drainage. This indicates that, for a given amount of drainage, the axial length of the drainage housing 200 in accordance with Figs. 7-9, can be reduced by approximately one-half relative to the axial length of the corresponding component in the Pressafiner configuration. This would result in a further cost reduction in favor of the ring-type drain housing 200.

The results of this comparative experiment showed that the combination of the stacked ring drainage housing 200 and the adjustable plug breaker discharge housing 380, produce drainage and chemical uptake for effective chemical impregnation. The one-piece screw 600, stacked ring drainage housing 200, and plug breaker discharge module 380 permit significant cost savings in construction relative to the Pressafiner configuration which has worms and collars,

composite shaft, and a drainage component consisting of conventional cages and bars.

What is claimed is:

1. In a screw device including a compression screw having a flight portion and a substantially smooth cylindrical downstream end portion, the screw supported on a device axis in the direction of which material is transported and condensed by the screw flights, and a discharge end housing for receiving the smooth cylindrical downstream end of the screw, wherein the end housing comprises:

a substantially tubular casing having upstream and downstream axial ends and a cylindrical inner wall defining a bore centered on the axis, and

a plurality of breaker plates extending from the wall into the bore.

2. The screw device of claim 1, wherein

the end housing includes a bearing member coaxially located within the casing for rotatingly supporting the downstream end of the screw, and

the breaker plates are rigidly connected to the bearing member.

3. The screw device of claim 1, wherein each breaker plate includes a front edge surface having a thickness that is transverse to the material flow through the housing, and a substantially planar side surfaces, each of the side surfaces having an area greater than the area of the front edge surface.

4. The screw device of claim 2, wherein each breaker plate includes a front edge surface having a thickness that is transverse to the material flow through the housing, and a substantially planar side surfaces, each of the side surfaces having an area greater than the area of the front edge surface.

5. The screw device of claim 4, wherein the plates are connected tangentially to the bearing member.

6. The screw device of claim 1, wherein the bearing member has a closed downstream end, and one of the plates has a radial channel therethrough for supplying lubricating liquid to the bearing closed end during use.

7. The screw device of claim 1, including means penetrating the casing, for adjusting the flow resistance through the bore.

8. The screw device of claim 7, wherein the means penetrating the casing include a plurality of radially adjustable pegs.

9. The screw device of claim 8, wherein some of the pegs are axially offset from the other pegs.

10. A discharge end housing for a screw device, comprising:

a substantially tubular casing including a cylindrical inner wall defining a bore having a flow area extending from a first axial end opening which is adapted to receive the screw to a second axial end opening adapted to discharge material;

a bearing member centered on the axis of the bore, for rotatably supporting the screw;

means connected between the bearing member and the cylindrical wall, for rigidly supporting the bearing member; and

means penetrating the casing into the bore, for adjusting the flow resistance through the flow area.

11. The discharge housing of claim 10, wherein the means for adjusting include a plurality of radially adjustable peg members.

12. The discharge housing of claim 11, wherein the peg members are axially staggered.

13. The discharge housing of claim 11, wherein the peg members are adjusted by bolt means passing radially through the casing.

14. The discharge housing of claim 13, wherein the casing includes an external boss for each peg member,

the bolt means includes a radial bore in the boss and means for radially advancing and withdrawing a rod member through the bore, and

said peg member is connected at one end to the rod member in the boss and extends at the opposite end into the flow area.

15. The discharge housing of claim 12, wherein each peg member has a smooth, abrasion resistant outer surface.

16. A screw device for condensing stock material, comprising:

drive means including a drive housing and a drive bearing assembly within the drive housing;

inlet means connected to the drive means and including an inlet housing, and an inlet opening for receiving stock material into the device;

processing means connected to the inlet means and including a processor housing;

discharge means connected to the processing means and including a discharge housing having an outlet opening for discharging condensed material from the device, said processor housing and discharge housing having respective coaxially aligned housing bores which define a longitudinal flow bore through the device;

a screw extending axially on the longitudinal flow bore and having

a first portion supported for rotation by the drive bearing assembly,

a second portion disposed in the inlet means in fluid communication with the inlet opening for receiving and advancing the stock material toward the processing means,

a third portion disposed in the processing housing bore for densifying the stock material by condensing the material against the processor housing, and

a fourth portion at least partly disposed in the discharge housing bore; and

means supported by at least one of the processor housing and discharge housing, for changing the cross sectional flow area of the longitudinal flow bore upstream of the outlet opening.

17. The screw device of claim 16, wherein the means for changing is supported by the processor housing.

18. The screw device of claim 17, wherein the processor housing includes a plurality of casing segments and the means for changing include at least one replaceable liner member supported within a respective at least one segment, for changing the cross section of the processor housing bore.

19. The screw device of claim 18, wherein all portions of the screw are integrally formed as a unitary screw.

20. The screw device of claim 16, wherein the means for changing is supported by the discharge housing.

21. The screw device of claim 20, wherein the means for changing include a plurality of peg members that radially penetrate the discharge housing an adjustable distance into the discharge bore.

22. The screw device of claim 21, wherein all portions of the screw are integrally formed as a unitary screw.

23. A screw device for condensing stock material, comprising:

a drive module including a drive housing, a drive bearing assembly within the drive housing, and a drive flange at one end of the drive housing;

an inlet module including an inlet housing, a first inlet flange sealingly engaging the drive flange, an inlet opening for receiving stock material into the device, and a second inlet flange;

a processing module including a processor housing, a first processor flange sealingly engaging the inlet second flange, and a processor second flange;

a discharge module including a discharge housing, a discharge flange sealingly engaging the processor second flange, and discharge means defining an outlet opening for discharging condensed material from the device, said processor housing and discharge housing having respective coaxially aligned housing bores which define a longitudinal bore through the device;

a screw extending axially on the longitudinal bore and having

a first portion supported for rotation by the drive bearing assembly,

a second portion disposed in the inlet module in fluid communication with the inlet opening for receiving and advancing the stock material toward the processing module,

a third portion disposed in the processing housing bore for densifying the stock material by condensing the material against the processor housing, and

a fourth portion at least partly disposed in the discharge housing bore; and

means for adjusting the cross sectional flow resistance of the discharge housing bore upstream of the outlet opening.

24. The screw device of claim 23 wherein said means for adjusting are radially movable within the discharge housing while the discharge module is engaged to the processing module.

25. The screw device of claim 24, wherein said means for adjusting include actuator means external to the discharge housing, for effecting said radial movement within the discharge housing.

26. A screw device for condensing stock material, comprising:

a drive module including a drive housing, a drive bearing assembly within the drive housing, and a drive flange at one end of the drive housing;

an inlet module including an inlet housing, a first inlet flange sealingly engaging the drive flange, an inlet opening for receiving stock material into the device, and a second inlet flange;

a processing module including a processor housing, a first processor flange sealingly engaging the inlet second flange, and a processor second flange;

a discharge module including a discharge housing, a discharge flange sealingly engaging the processor second flange, and discharge means defining an opening for discharging condensed material from the device, said processor housing and discharge housing having respective coaxially aligned housing bores which define a longitudinal bore through the device;

a screw extending axially on the longitudinal bore and having

a first portion supported for rotation by the drive bearing assembly,

a second portion disposed in the inlet module in fluid communication with the inlet opening for receiving and advancing the stock material toward the processing module,

a third portion disposed in the processing housing bore for densifying the stock material by condensing the material against the processor housing, and

a fourth portion at least partly disposed in the discharge housing bore, for guiding the condensed material from the processing module toward the discharge opening; and

means for changing the cross sectional flow area within an axially extending portion of the processor housing bore, without removing the screw from said longitudinal bore.

27. The screw device of claim 26, wherein said processing module includes a plurality of casing segments defining the processor housing, and the means for changing include at least one replaceable liner member supported within a respective at least one casing segment, whereby the flow cross section of the processor housing bore depends on the radial thickness of the liner member.

28. The screw device of claim 27, wherein the liner members contain a multiplicity of radial flow channels for draining liquid from the stock material.

29. A screw device for condensing stock material, comprising:

a drive module including a drive housing, a drive bearing assembly within the drive housing, and a drive flange at one end of the drive housing;

an inlet module including an inlet housing, a first inlet flange adapted to sealingly engage the drive flange, an inlet opening for receiving stock material into the device, and a second inlet flange;

a processing module including a processor housing, a first processor flange adapted to sealingly mate with the inlet second flange, and a processor second flange;

a discharge module including a discharge housing, a discharge flange adapted for sealing engagement with the processor second flange, and discharge means defining an opening for discharging condensed material from the device, said processor housing and discharge housing having

respective coaxially aligned housing bores which define a longitudinal flow bore through the device; and

a screw extending axially on the longitudinal bore and having

a first portion supported for rotation by the drive bearing assembly,

a second portion disposed in the inlet module in fluid communication with the inlet opening for advancing the stock material toward the processing module,

a third portion disposed in the processing module for densifying the stock material by condensing the material against the processor housing, and

a fourth portion at least partly disposed in the discharge module;

wherein the processing module contains a multiplicity of radial flow channels for draining liquid from the stock material, and includes means for changing the flow area of said channels without removing the screw from the longitudinal flow bore.

30. The screw device of claim 29, wherein

the processing module contains at least one liner member in which at least some of the radial flow channels are formed, and

the means for changing include a replacement liner having a different radial flow area.

31. The screw device of claim 29 wherein

the processing module contains a multiplicity of axially stacked rings defining said flow channels between the rings, and

the means for changing includes replaceable shims situated between the rings.

32. A screw press housing having an axially extending internal bore for coaxially receiving a screw, and an external surface surrounding the bore, comprising:

a plurality of axially elongated casing members, each casing member in cross section having,

a concave inner surface which defines an arc segment having a first radius of curvature,

a convex outer surface defining a portion of the external surface of the housing, and

fixture means for attaching together adjacent casing members, whereby said inner surfaces of the attached casing members define a first bore;

a plurality of bar members, each situated between two arc segments of the attached casing members and having an inner end extending radially inwardly into the first bore;

at least one axially elongated liner member coaxially retained within the first bore, each liner member in cross section having,

a convex outer wall supported by a casing member against radially outward movement,

a concave inner wall having a second radius of curvature that is smaller than the first radius of curvature, and

spaced apart end surfaces, each end surface juxtaposed with the inner end of a bar member;

whereby said screw bore is defined at least in part by said inner wall.

33. The screw housing of claim 32, including adjustment means accessible at the housing exterior and passing through the casing member into the first bore, for defining an adjustable radial stop for the liner outer wall.

34. The screw housing of claim 32, wherein,

the housing has four casing members attached together with four bar members,

only two liner members are provided, coaxially retained within a respective two casing members, and

the inner surface of the first bore and the inner wall of the liner members each define substantially one-half of the screw bore.

35. The screw housing of claim 34, wherein the inner end of each bar member extends radially inward beyond the liner member inner wall.

36. The screw housing of claim 32, wherein the housing has two casing members and two liner members and the screw bore is defined only by the inner walls of the liner members.

37. The screw housing of claim 32, wherein the screw bore is defined in part by the inner surface of at least one casing member and in part by the inner wall of at least one liner member.

38. The screw housing of claim 37, wherein at least one of the inner surfaces and inner walls that define the screw bore include channel means for conveying pressate out of the screw bore during operation of the screw device.

39. The screw housing of claim 38, wherein said channel means are formed only in the casing member inner surface that defines part of the screw bore.

40. The screw housing of claim 38, wherein said channel means are formed only in the liner members.

41. The screw device of claim 35, wherein the inner ends of at least one bar member include a radially oriented groove for draining pressate out of the screw bore.

42. The screw drive of claim 32, wherein each end surfaces of the liner member substantially abuts a bar member inner end.

43. A compression screw device having a drain housing including a screw bore defining a housing axis for coaxially receiving a rotating screw, and a frame for supporting the housing, wherein the the housing comprises:

a plurality of substantially annular rings rigidly stacked together coaxially along the housing axis, each

ring having an inner profile defining a substantially circular central opening in alignment with the openings of the other stacked rings to form the screw bore, and an outer profile including means for engaging the frame; and

shim means located between adjacent rings, for maintaining a drainage channel between adjacent rings that extends radially away from the screw bore to the outer profile.

44. The compression screw device of claim 43, including at least one anti-rotation projection extending radially into and longitudinally along the screw bore.

45. The compression screw device of claim 44, wherein the inner profile of each ring includes a radially extending groove which is in registry with other grooves to form a slot, and the anti-rotation projection is a bar member received in and supported by the slots.

46. The compression screw device of claim 43, including

a plurality of holes through the annulus of each ring, spaced in a pattern around the inner profile in respective alignment with the hole pattern on the other rings, and

means passing in tension longitudinally through each hole for drawing the rings axially toward each other to form said rigid stack.

47. The compression screw device of claim 43, wherein the means on the outer profile include at least two notches for engagement with a respective at least two longitudinally extending bars carried by the frame.

48. The compression screw device of claim 43, wherein said means for engaging the frame engages a support bar supported by the frame and spanning the outer profile of the rings, for preventing rotation of the housing relative to the frame.

49. The compression screw device of claim 43, wherein the shim means is integrally formed as thickened areas on each ring.

50. The compression screw device of claim 44, wherein the anti-rotation projection is formed by back-to-back integrally formed projection on the inner profile of each ring.

51. The compression screw device of claim 43, including,

an end plate at each axial end of the stacked rings, and

tension means connected between the end plates, for drawing the end plates and rings axially toward each other to form said rigid stack.

52. The compression screw device of claim 51, wherein the tension means includes a plurality of tension bolts which longitudinally traverse the stacked rings immediately outside the ring outer profile.

53. A ring for constituting a portion of a drain housing supported in a screw device, wherein said ring comprises:

an annular body portion having inner and outer circumferential edges, a radial depth between the edges, and an axial thickness;

a plurality of shim regions spaced apart on the body portion and having an axial thickness greater than the body axial thickness; and

notch means formed in the body portion outer edge, for engaging positioning and support means on the screw device.

54. The drain housing ring of claim 53, wherein the ring inner edge has an axial thickness different from the body thickness.

55. The drain housing ring of claim 53, including means projecting inwardly from the inner edge, for defining a portion of a screw bore anti-rotation member.

56. The drain housing ring of claim 53, wherein said ring is stacked axially against another substantially identical ring,

each of said stacked rings includes means projecting inwardly from the inner edge for defining a portion of a screw bore anti-rotation member, and

when the notch means of the stacked rings are in registry, each shim region of one ring is in contact with the other ring,and each of said means on one ring is substantially in contact with a corresponding means on the other ring such that said means form an anti-rotation bar extending in the axial direction along the inner edges of the rings.

57. A method of forming a screw press housing with a longitudinal screw bore having an adjustable cross sectional flow area, comprising the steps of:

selecting a plurality of axially elongated casing members adapted to be attached together and thereby define in cross section, a concave inner surface defining a first arc with a first radius of curvature,

positioning a discrete, axially elongated liner member within the inner surface of at least one casing member, the liner member having a concave inner wall defining a second arc with a second radius of curvature;

securing the liner member against radial and rotational movement relative to the casing member; and

attaching the casing members together to form the housing with a screw bore cross sectional area defined at least in part by the inner wall of the liner member on said at least one casing member.

58. The method of claim 57, further including the step of adjusting the bore cross sectional area by replacing at least one liner member with another liner member having a radius of curvature of the inner wall that is different from said second radius of curvature.

59. The method of claim 58, including the step of rigidly supporting a radially extending bar member at the ends of the arc defined by the liner member.

60. The method of claim 59, wherein the step of rigidly supporting the bar member includes supporting the bar member between adjacent casing members during the step of attaching the casing members together.

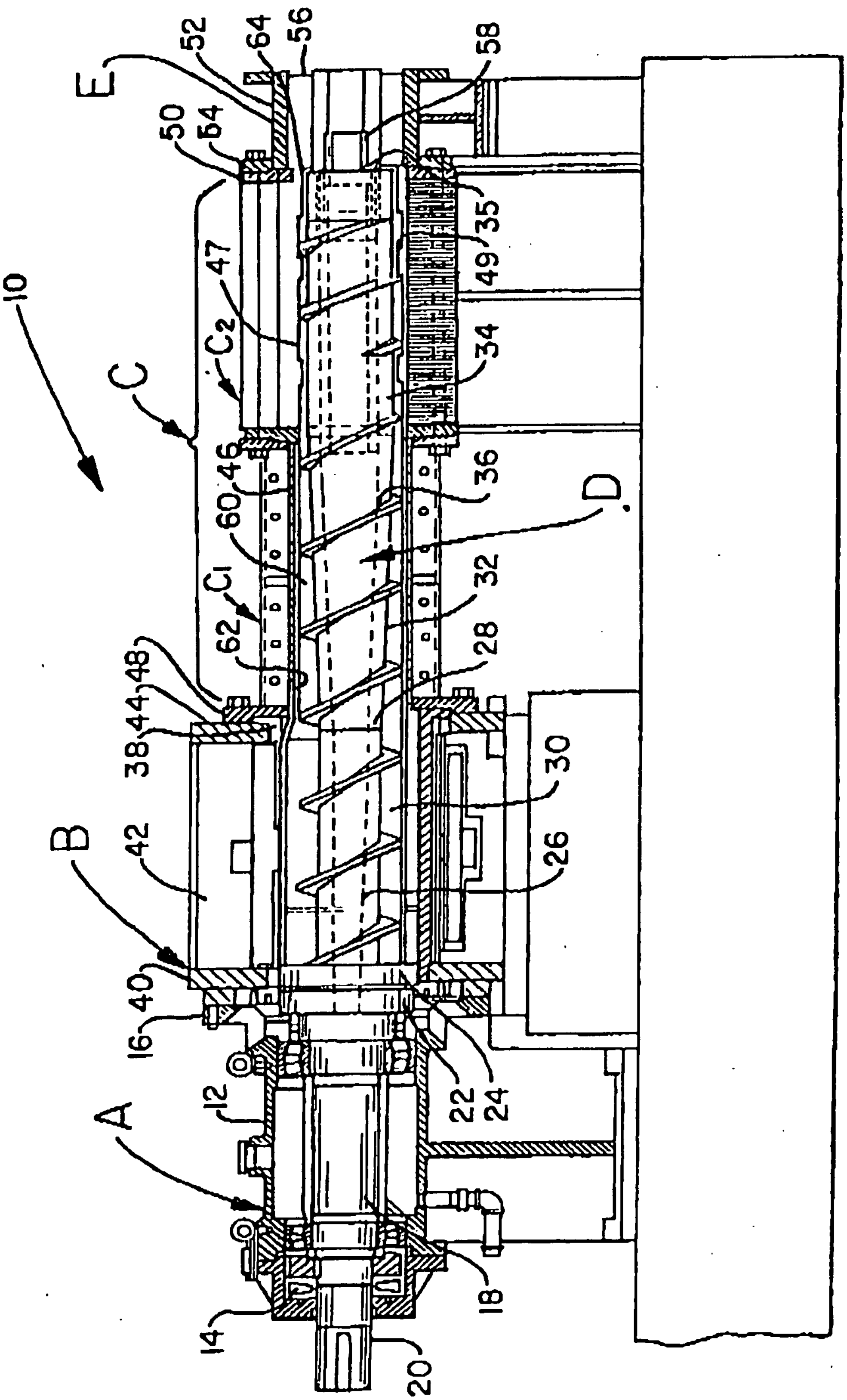
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Fig. 1

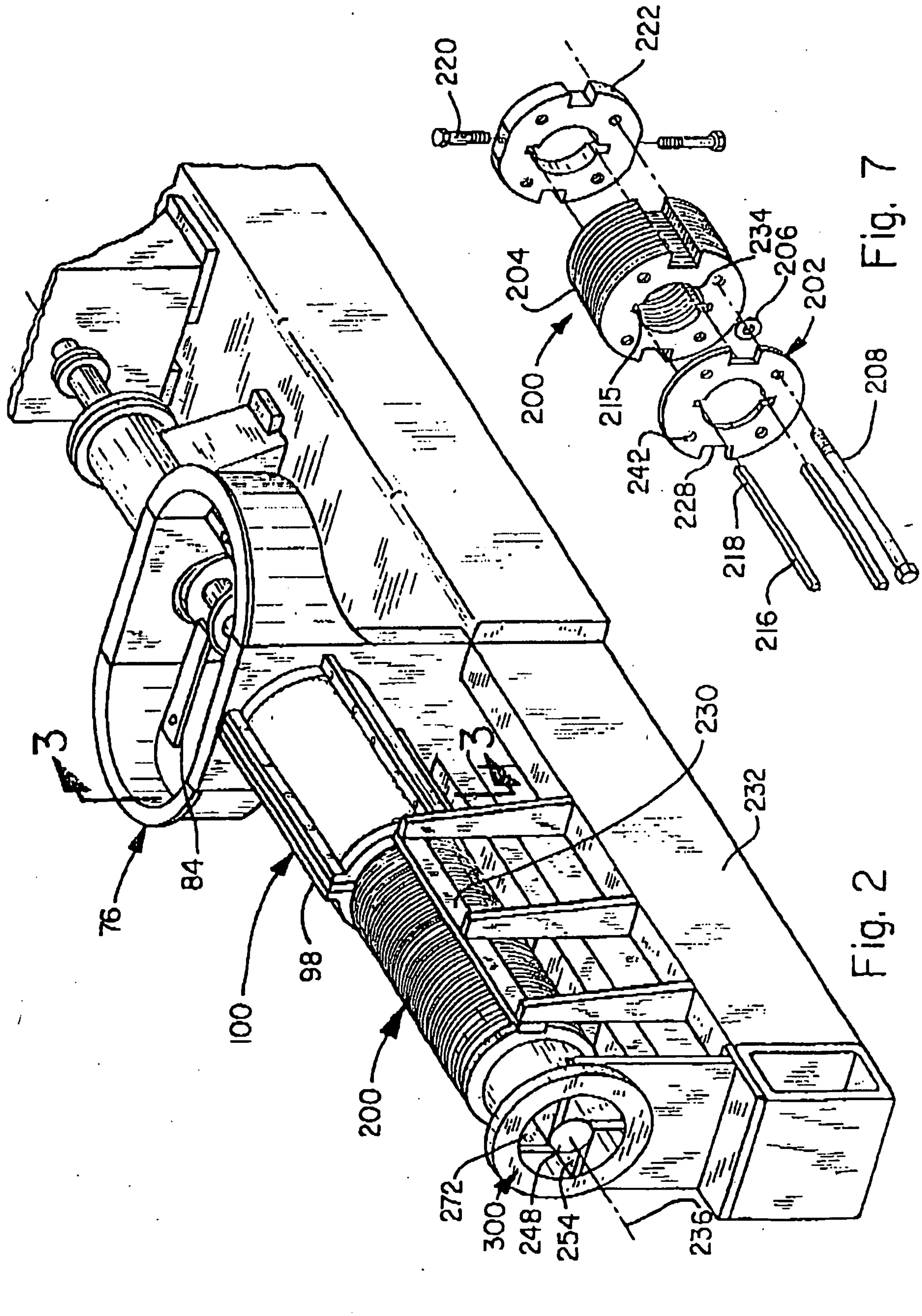
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Fig. 7

Fig. 2

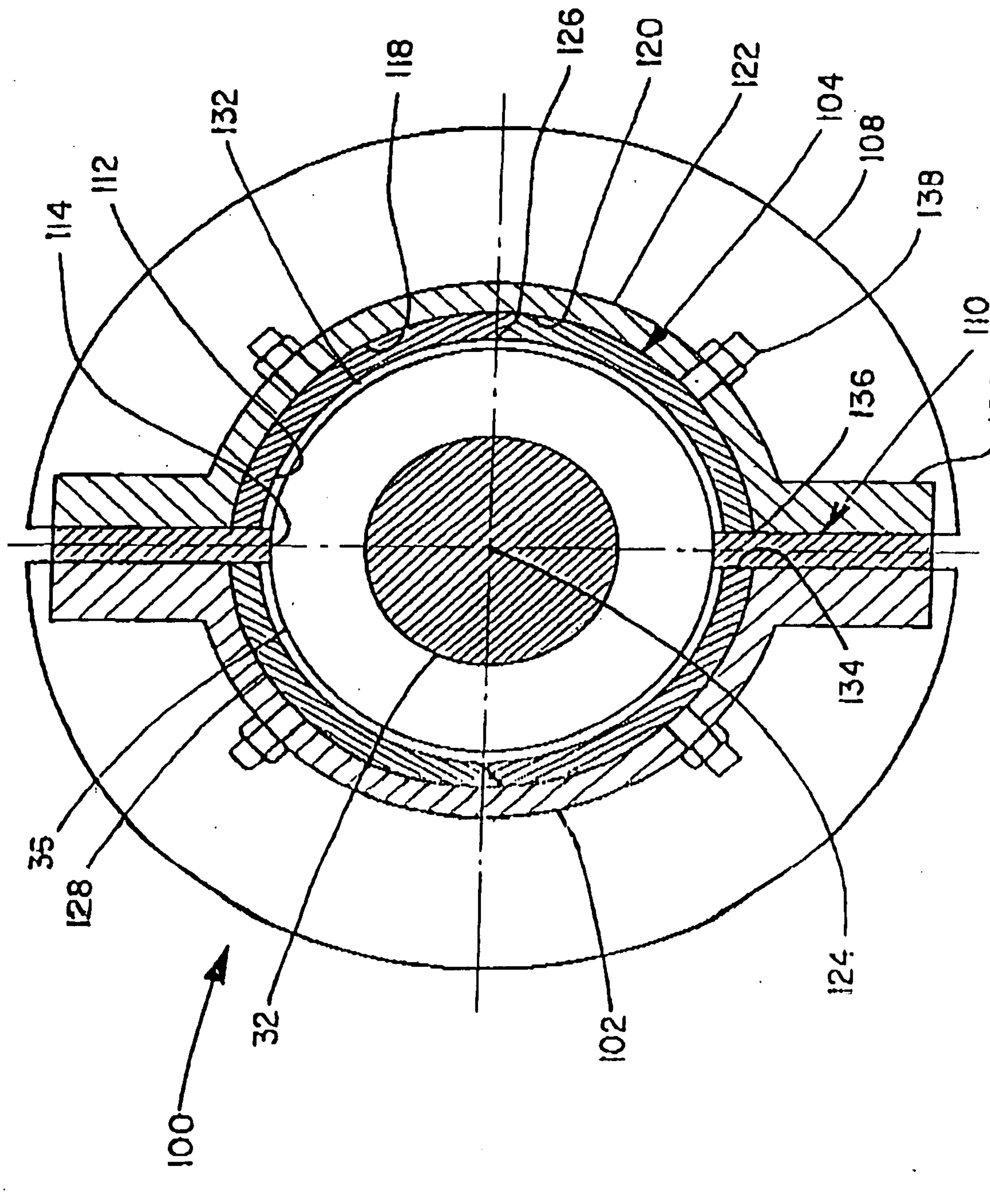
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Fig. 3

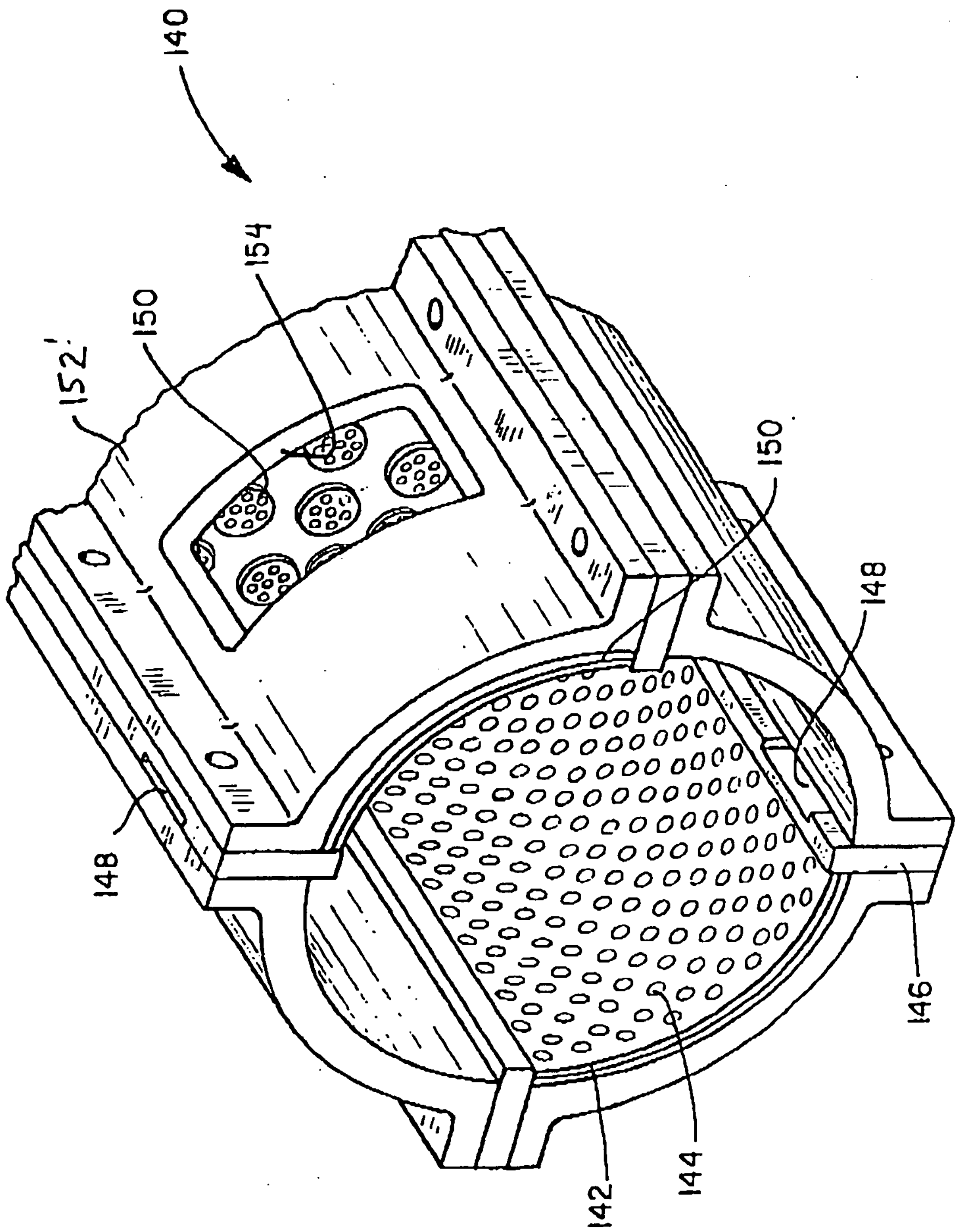

Fig. 4

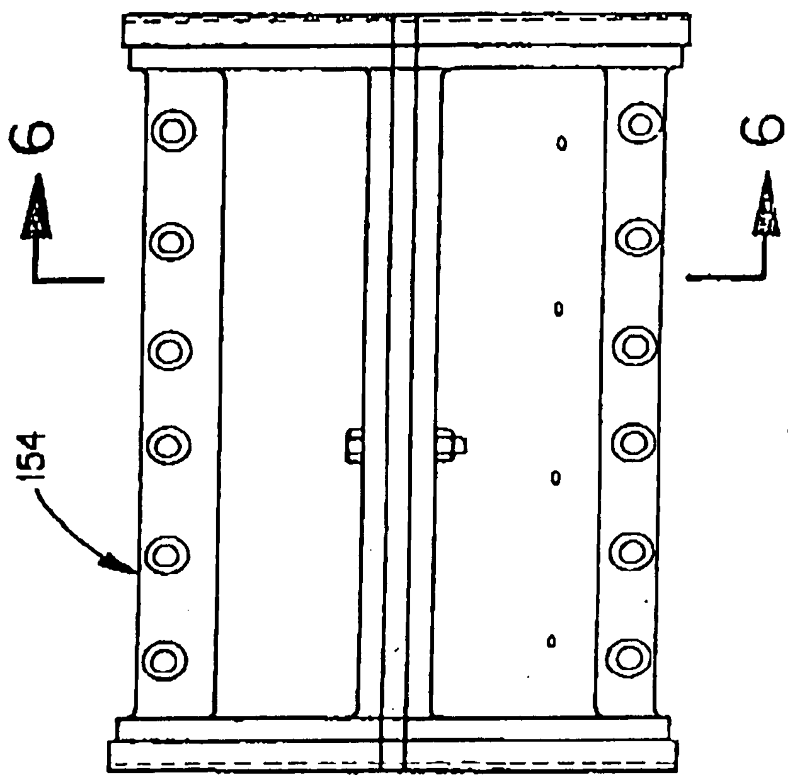

Fig. 5

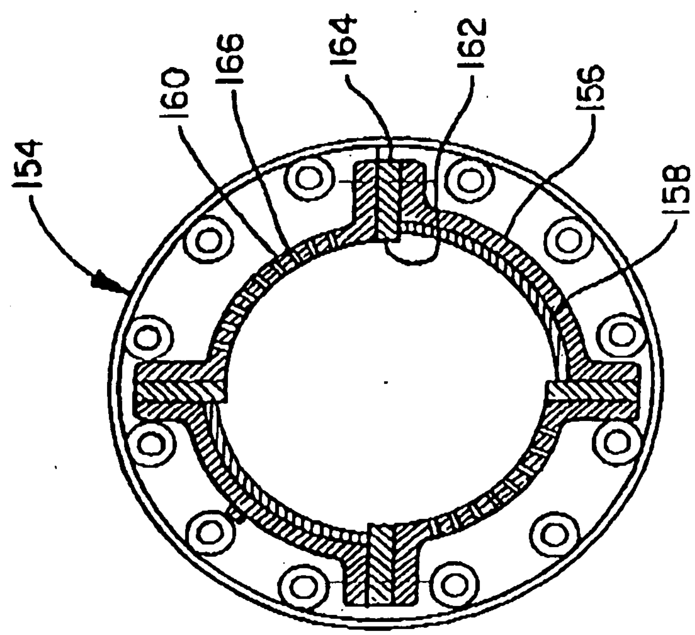

Fig. 6

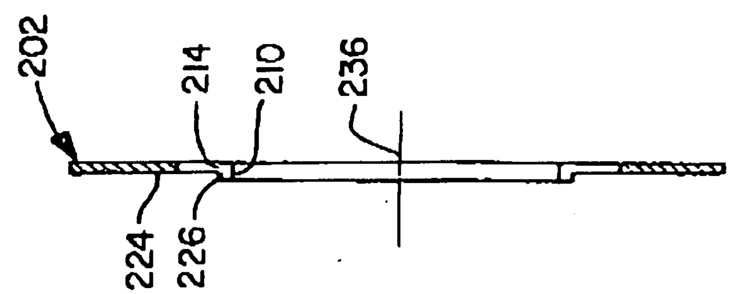

Fig. 9

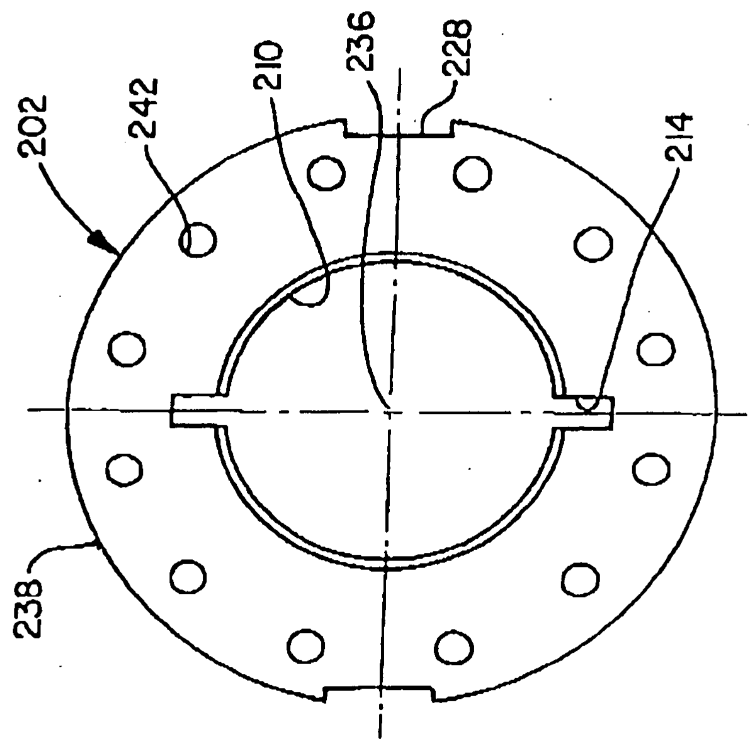

Fig. 8

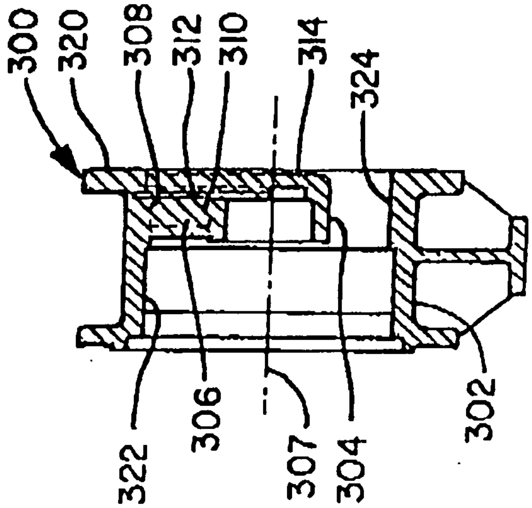
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Fig. 11

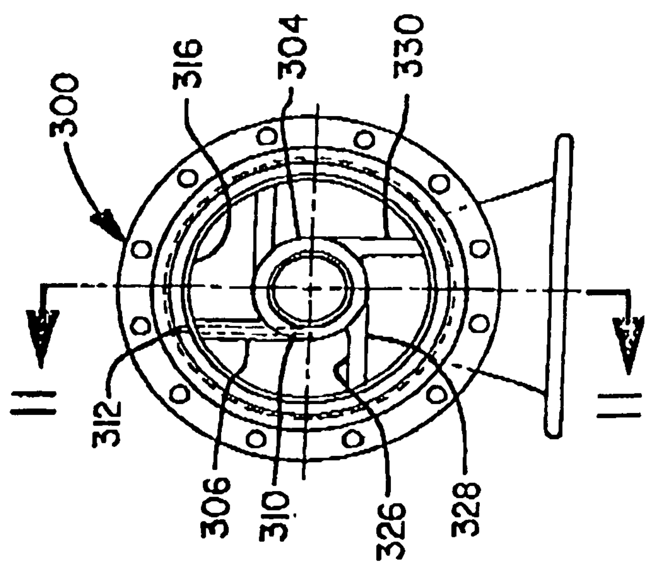
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Fig. 10

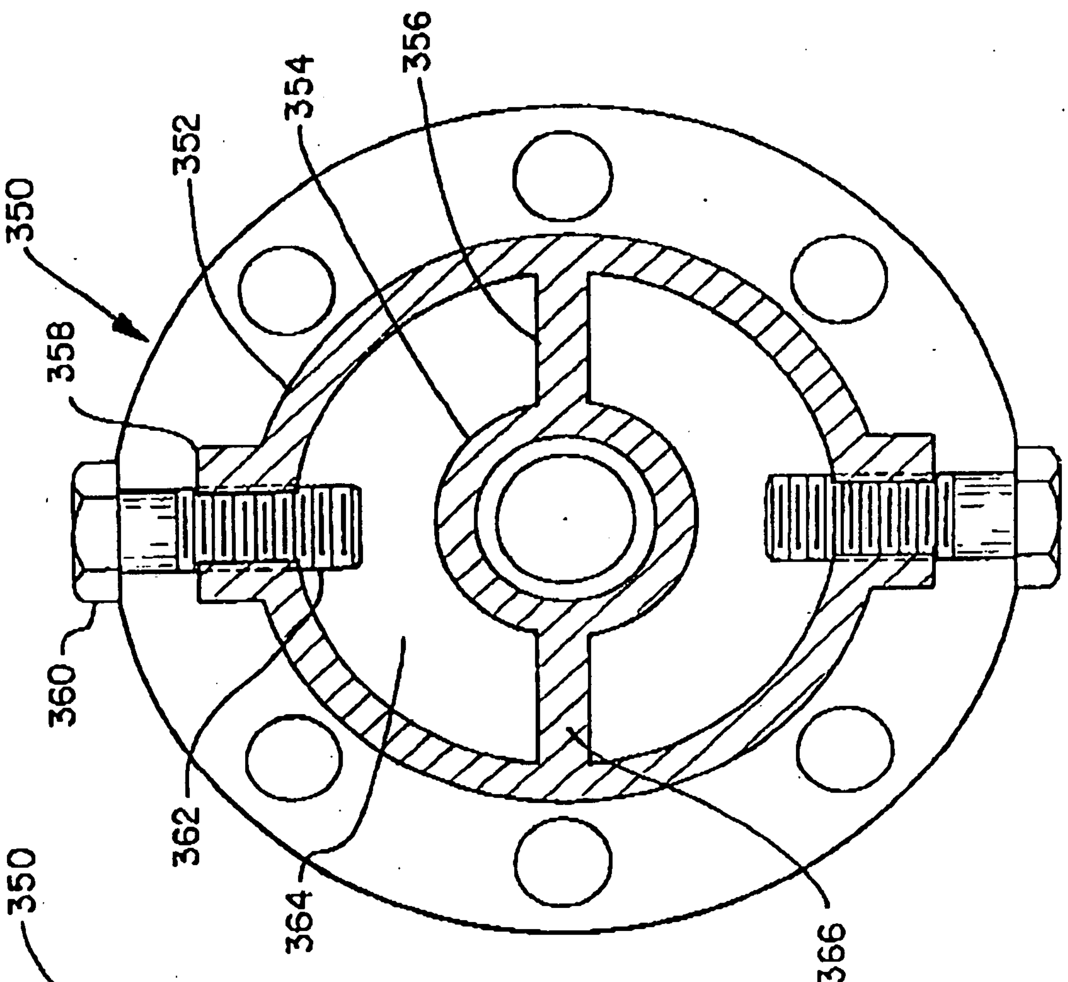

Fig. 12

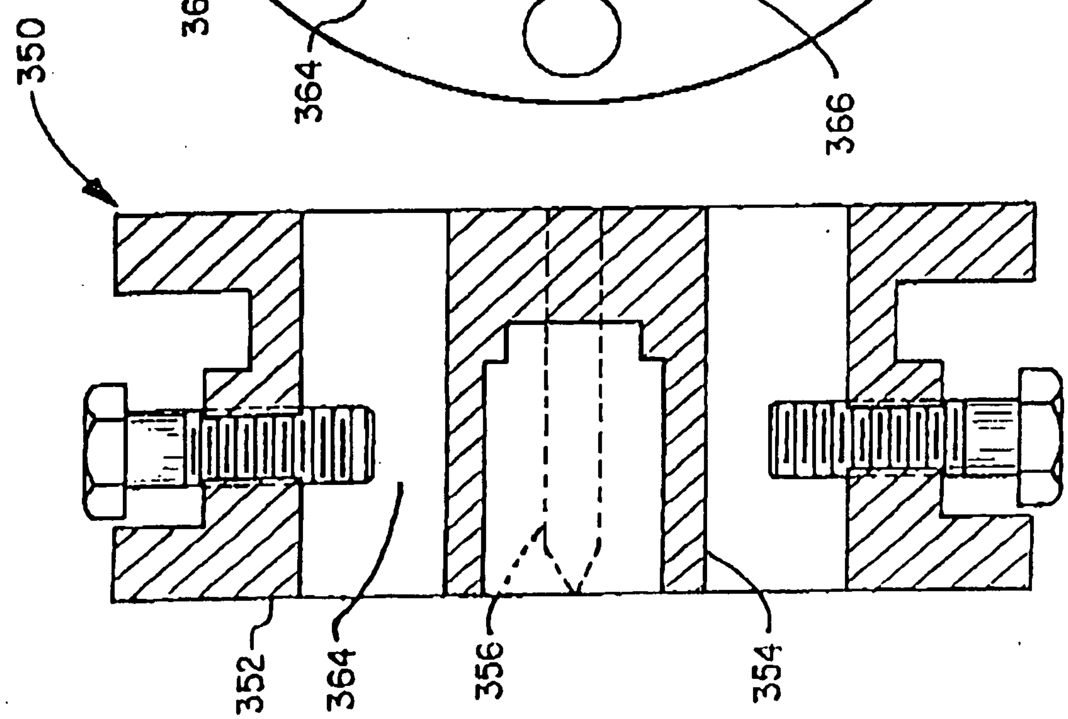

Fig. 13

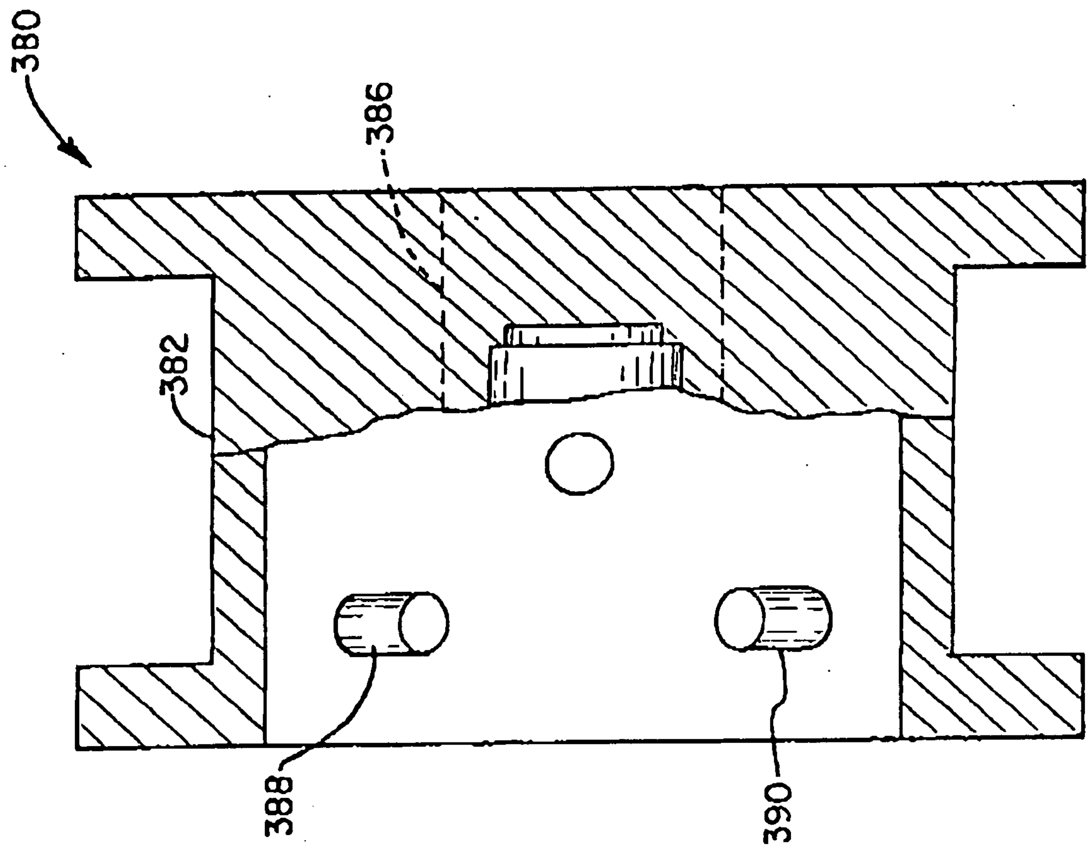

Fig. 15

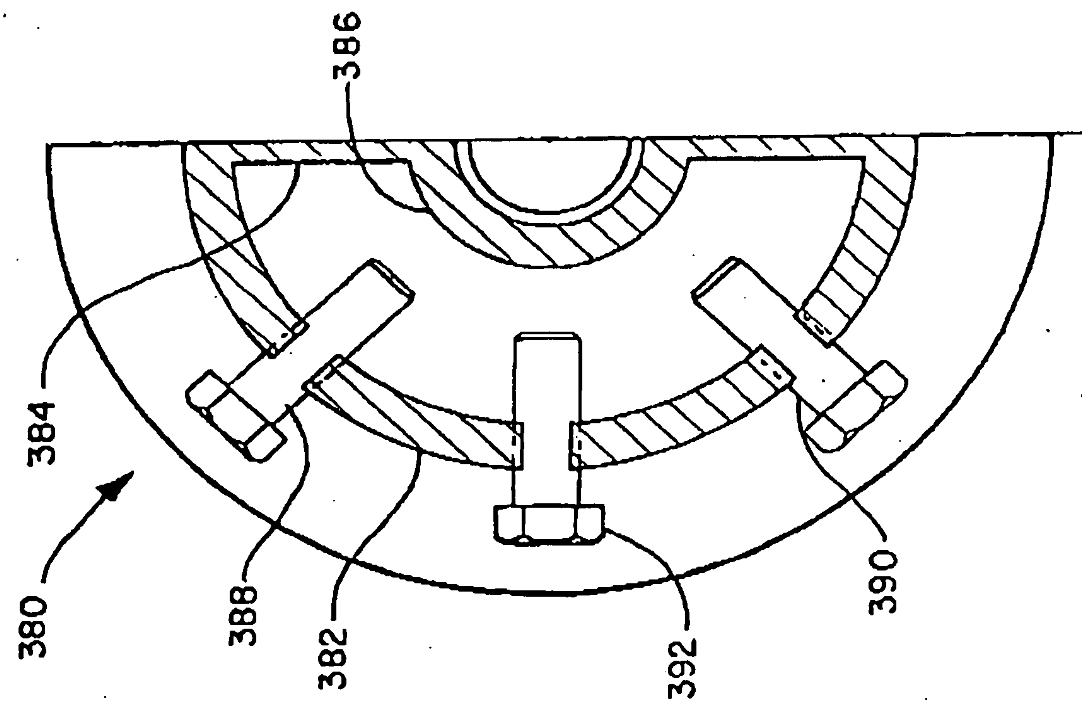

Fig. 14

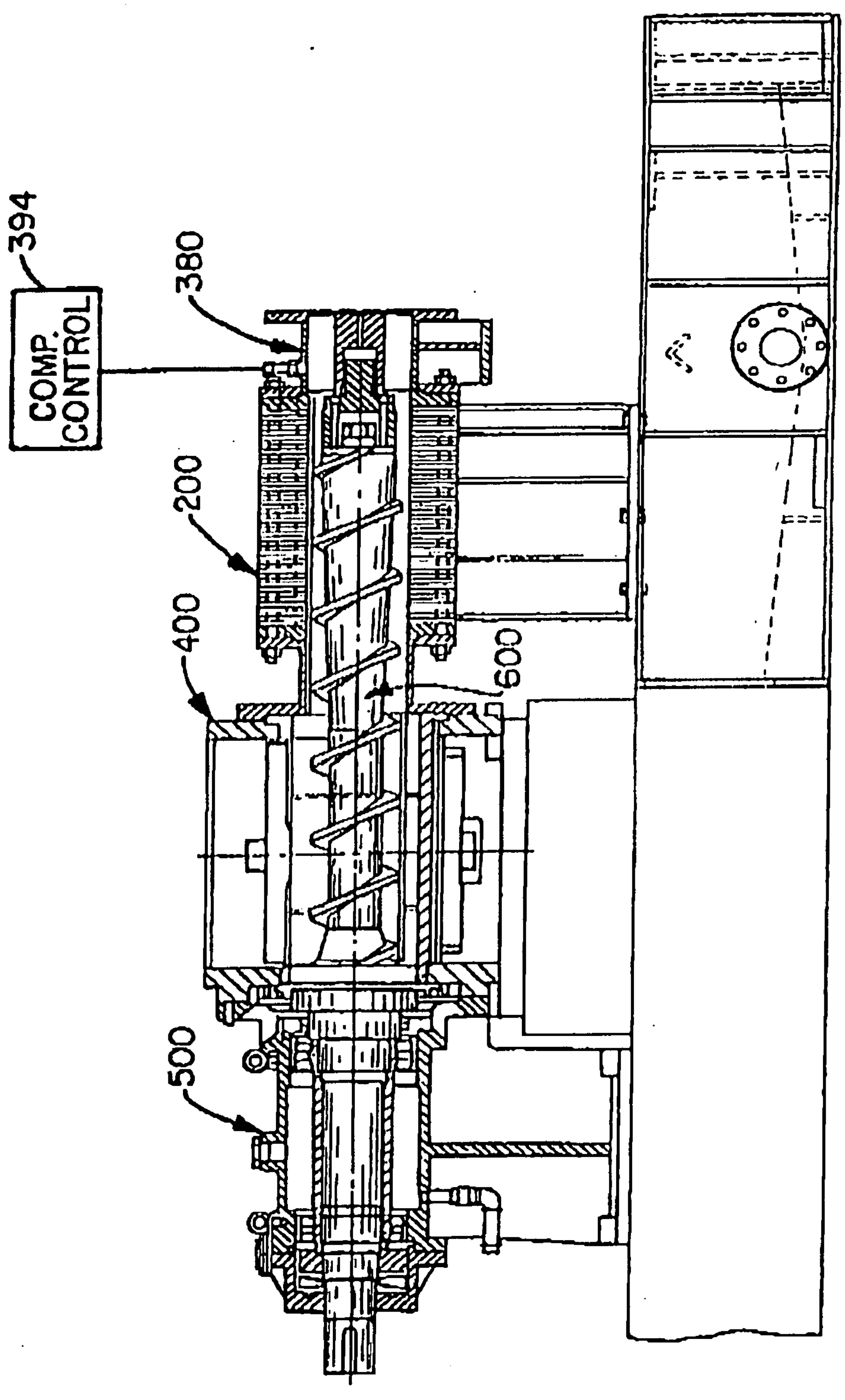

Fig. 16

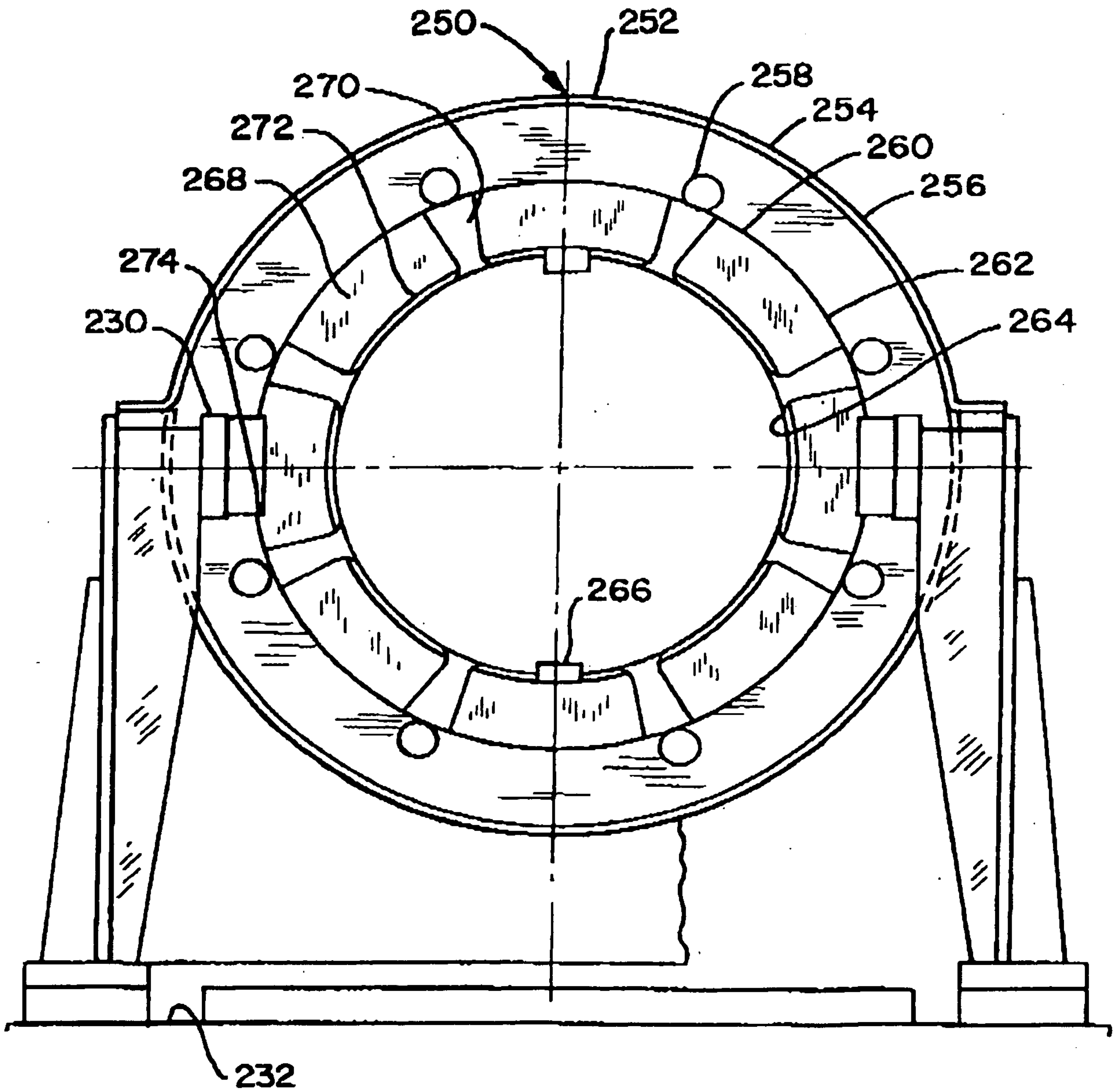

Fig. 17

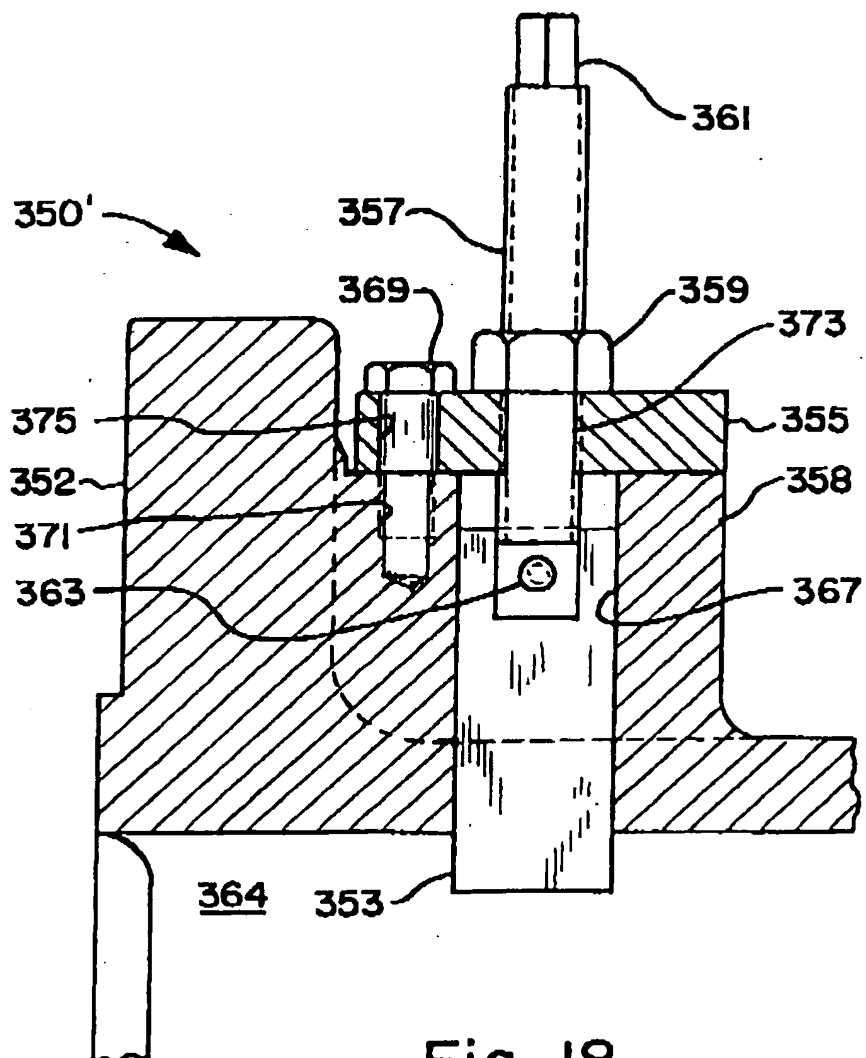

Fig. 18

INTERNATIONAL SEARCH REPORT

International Application No. PCT/US92/00939

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC
IPC(5) B30B 9/14
U.S. Cl. 100/128, 145

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
U.S. Cl.	100/116, 117, 126-129, 145-150

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X	US, A, 1,902,738 (Tuttle) 21 March 1933, See figures 1, 6 and 8; page 1, lines 77-86; page 2, lines 46-55 and page 2, lines 104-115.	1-4
X	US, A 3,288,056 (Ginaven) 29 November 1966, See figures 1, 2, 3, and 4.	1 and 7-9
A	US, A 4,429,551 (Hizume) 07 February 1984, See figures 4-6.	1-9
A	US, A 3,695,173 (Cox) 03 October 1972, See page 8, lines 3-6.	6

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
02 June 1992	26 JUN 1992
International Searching Authority	**Signature of Authorized Officer**
ISA/US	Stephen F. Gerrity

International Application No. PCT/US92/00939

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [1]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers . . . . , because they relate to subject matter [12] not required to be searched by this Authority, namely:

2. ☐ Claim numbers ...., because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out [13], specifically:

3. ☐ Claim numbers____________, because they are dependent claims not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI. ☒ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [2]

This International Searching Authority found multiple inventions in this international application as follows:

Group I: Claims 1-9
Group II: Claims 10-15
Group III: Claims 16-31
Group IV: Claims 32-42 and 57-60
Group V: Claims 43-52
Group VI: Claims 53-56

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.
2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:
3. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers: 1-9
4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.